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ADAPTIVE MODULATION OF SIGNALS IN MIMO CHANNELS

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На основі моделювання з використанням пакету MATLAB проведено аналіз виграшу у відношенні сигнал/шум при використанні адаптивної модуляції сигналів у каналах MIMO систем WiMAX.

By using mathematical simulation it is carrying out analysis of advantages of using adaptable modulation of signals in MIMO channels of WiMAX systems.

На основе моделирования в среде MATLAB проведен сравнительный анализ выигрыша в отношении сигнал/шум при использовании адаптивной модуляции сигналов в каналах MIMO систем WiMAX.

Introduction

MIMO technology is a very important technique used to increase the signal to noise ratio for wireless technologies, especially in mobile WiMAX where there is a non line of site situation and it needs to be adaptable to the change in signal to noise ratio. So, the use of adaptable modulation is a very important concept for WiMAX systems. The purpose of the paper is investigating advantages of using adaptable modulation in WiMAX with MIMO.

I. MIMO system and adaptive modulation in WiMAX technology

In wireless access systems with fading in the channels of signal distribution like WiMAX systems receiving and transmission diversity is used, where comparative analysis of using transmission and receiving diversity methods in WiMAX technology were discussed in previous paper [1]. Virtual uncorrelated channels are formed either, by using multi-antenna system on the transmitter and on the receiver, or by using more than one frequency which is called frequency diversity, or by using time diversity. In such systems, for an optimal channel gain realization with interference immunity more than one signal is needed on the receiver side, which they are sent through different paths, and to use an optimal method for their combining. For that reason, in diversity systems an optimal scheme for signal combining is applied to achieve a maximal SNR.

In modern wireless mobile networks the most important need is for frequency resources, and to solve this problem, space diversity was used. A system of multi antenna that is called MIMO which uses space diversities is already used (figure 1), and it is also uses time diversity coding called STBC (space time block coding) or Alamouti [2-5]. This system, transmits the signal from each antenna by using the same frequency and in this way, it increases the channel capacity without using more frequency resources.

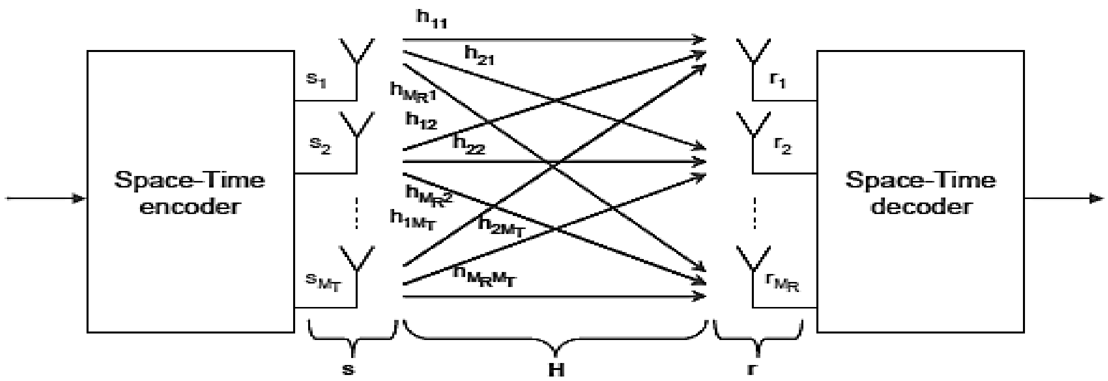

Fig. 1. MIMO system

The basic purpose of using MIMO antenna system is to increase the received signal to noise ratio by making use of the random fading channels coefficients as channel gain

$$\gamma = \sum_{i=1}^{N} \sum_{j=1}^{M} \left| h_{ij} \right|^2 \frac{\varepsilon_x}{\sigma^2 N}, \qquad (1)$$

where: γ – received signal to noise ratio;
N – number of transmitting antennas;
M – number of receiving antennas;
ε_x – transmitted power;
σ^2 – noise variance.

WiMAX technology uses a method called adaptive modulation, which allows the WiMAX system to adjust the signal modulation scheme depending on the signal to noise ratio (SNR) condition of the radio link. When the radio link signal level is high, the highest modulation scheme is used, giving the system more capacity. When the signal fades, the WiMAX system can shift to a lower modulation scheme to maintain the connection quality and link stability. This feature, allows the system to overcome time-selective fading. The key feature of adaptive modulation is to increase the range, since the system can flex to the actual fading conditions, by using different modulation schemes, which makes it adaptable for the worst case conditions. The combining of MIMO antenna and adaptive modulation method is a very effective way, that the mobile WiMAX technology uses in order to adapt to the fast changes in channel conditions and to increase the transmitting capacity and range. The system model that uses MIMO and adaptive modulation is shown in figure 2.

The Matlab simulation results for MIMO antenna system by using different modulation types is shown in figure 3, where the BPSK has the best performance with 5dB, QPSK 8dB, QAM16 15dB and QAM64 21dB. Those results show the adaptive modulation working limits, for each modulation type. Although, the above results are accurate and very close to the results that have been published before, but those results are ideal, because in the simulation process the amplitudes of the channel matrix coefficients are considered constant which indicates that the received signal to noise ratio in the receiver antennas is equal, and this is not an accurate assumption. But, despite that the above results can be used as a reference for building a general adaptive modulation algorithm. In fact, the received signal to noise ratio for MIMO antenna in different receiving antennas differs, and the reason for this difference is that each antenna has different channel gain as we see in equations:

$$Gain1 = \left(|h_{11}|^2 + |h_{21}|^2\right); \quad (2)$$

$$Gain2 = \left(|h_{12}|^2 + |h_{22}|^2\right). \quad (3)$$

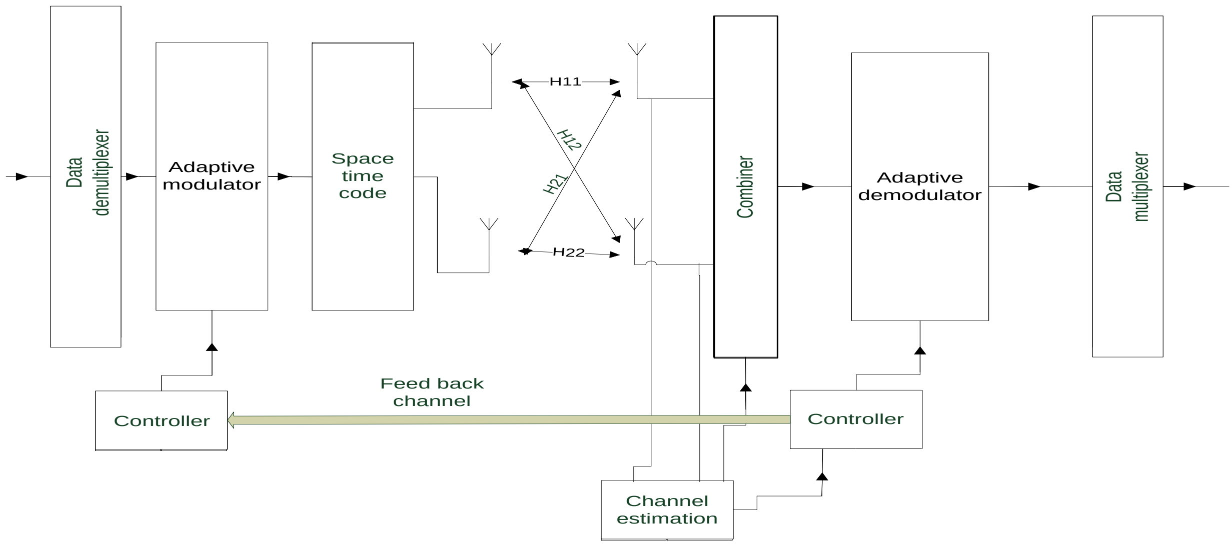

Fig. 2. Adaptive modulation with MIMO model

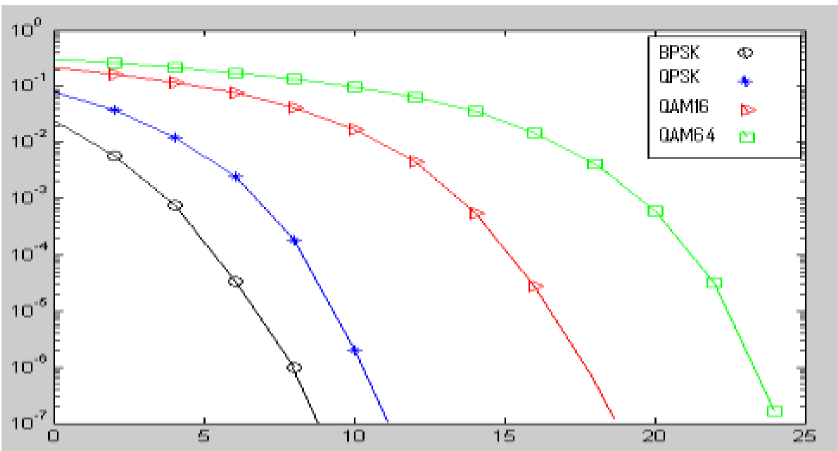

Fig. 3. Ideal BER results for adaptive modulation

The Matlab model were used to generate the fading channel effect for 2×2 MIMO antenna system by using equations (2) and (3), each channel coefficient is a random Gaussian process and all the coefficients are non correlated. The results for this simulation, are in figure 4 and the effect of the channel gain on a received signal to noise ratio value of 10dB is in figure 5.

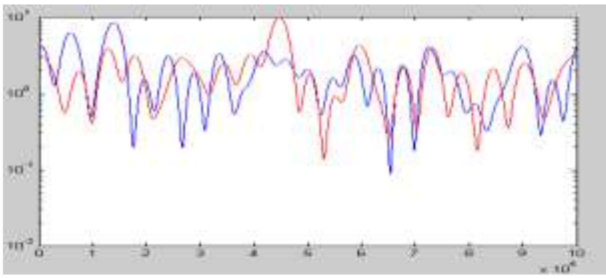

Fig. 4. MIMO channel gain

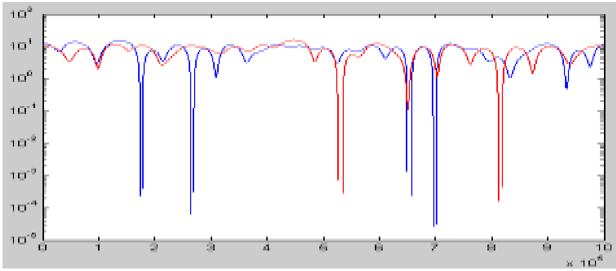

Fig. 5. Received SNR

The difference in performance between ideal situation where the channel gain is neglected, and where the channel gain effect, is taken in to account, is shown in figures 6 and 7. In figure 6 we see the performance of QAM64 with three different speeds 5km/h, 40km/h and 100km/h, where for 5km/h there is about 4dB degradation in performance, 4.5dB with 40km/h and 7dB with 100km/h. The same situation is for QAM16 as shown in figure 7, where it is 2.5 dB with 5km/h, 3.3 dB with 40km/h and 8dB with 100km/h. The reason for this degradation in performance, despite of the application of adaptive modulation with QAM64 and QAM16, where QAM16 start working over 15dB and QAM64 over 21dB is that the signal to noise ratio on a certain value is changing with time because of the change in gain for different fading channels as in figure 5 where the received signal to noise ratio is 10dB in a fixed distance between the transmitter and the receiver, but the receiving antennas are receiving unequal signal to noise ratio despite the fixed distance.

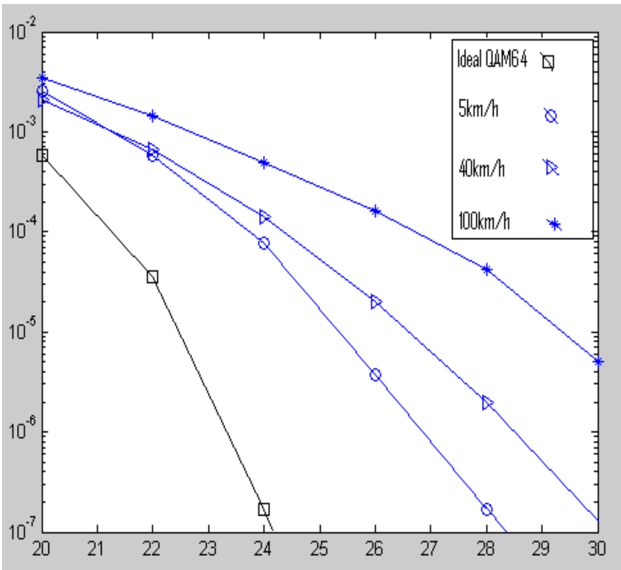

Fig. 6. QAM64 BER with different mobility speeds

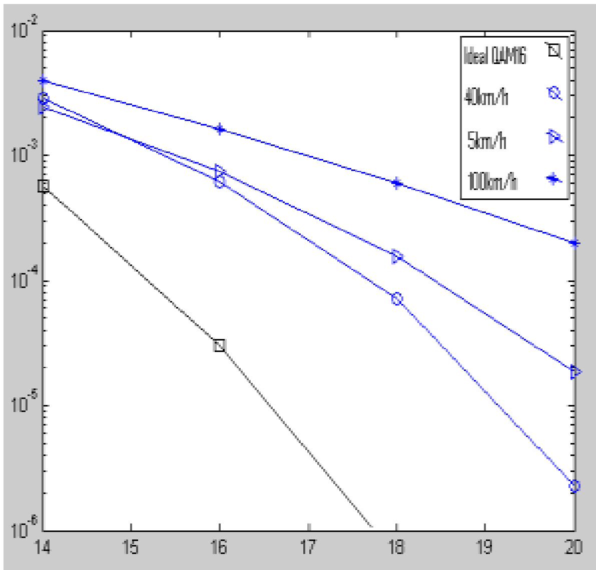

Fig. 7. QAM64 BER with different mobility speeds

II. Adaptive modulation in MIMO channels

The adaptive modulation in MIMO channels, is a new method that we are proposing, is based on the idea of using different types of modulation through different MIMO channels. Those modulation types should have different constellation order, for example, QAM64 and QPSK, so the use of modulation with lower constellation will lower the BER when using it through a channel with low gain, and using a high constellation order through a channel with high gain, will not lower the BER value as it is shown in figure 8.

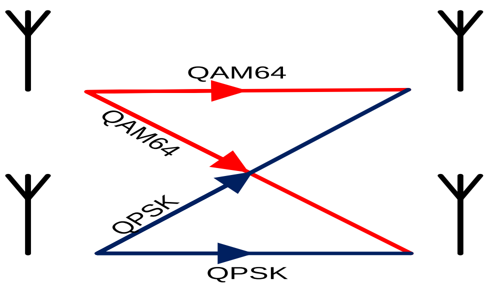

Fig. 8. Adaptive modulation in MIMO channels

The solution that we used for this problem, is the adaptive modulation in MIMO channels and the dual modulation. The first solution in which the transmitter is changing the modulation type for each antenna depending on the received signal level through each coherence time where in this system the receiver is using a feedback channel, while in the second solution the transmitter is using two different types of modulation in order to lower the bit error rate and in this system there is no feedback, but the system is using two modulation types, one with high constellation mode like QAM64 and the other with lower constellation mode like BPSK. The system model that uses the adaptive modulation in MIMO channels and dual modulation methods, is shown in figure 9.

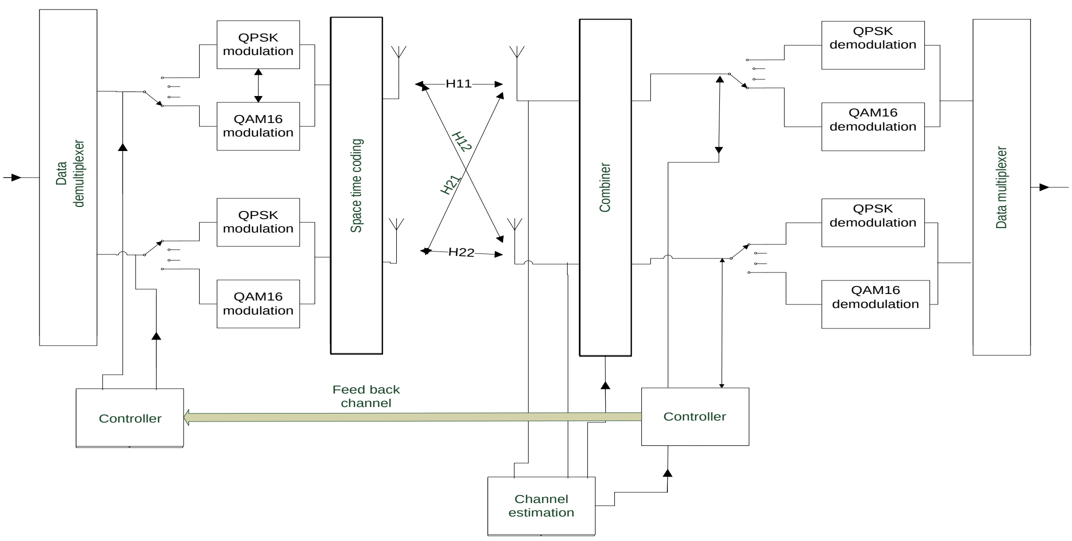

Fig. 9. Adaptive modulation in MIMO channels system model

III. Results of simulation

The simulation results for the above model, using the adaptive modulation in MIMO channels, are shown in figures 10, 11, and for using the dual modulation in figures 12, 13. In figure 10 QAM64 modulation is used with three different speeds, which shows the effect of mobility on MIMO performance. And the adaptive modulation in MIMO channels algorithm were used and we can see that the performance were enhanced completely for all the speed values, also in figure 11 the same thing were done but by using QAM16 verses the adaptive modulation in MIMO channels algorithm. In figures 12 and 13 we used dual modulation method with QAM64 and QAM16 and it shows that using BPSK and QPSK with QAM64 and QAM16 enhanced the performance for about 3dB with each speed value.

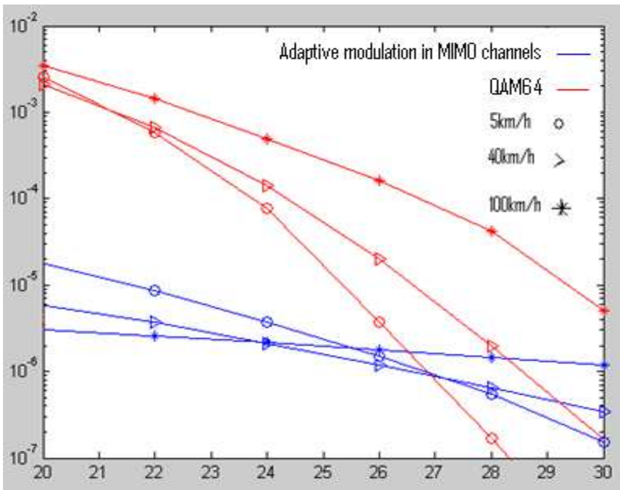

Fig. 10. Adaptive modulation in MIMO channels BER (results for QAM64)

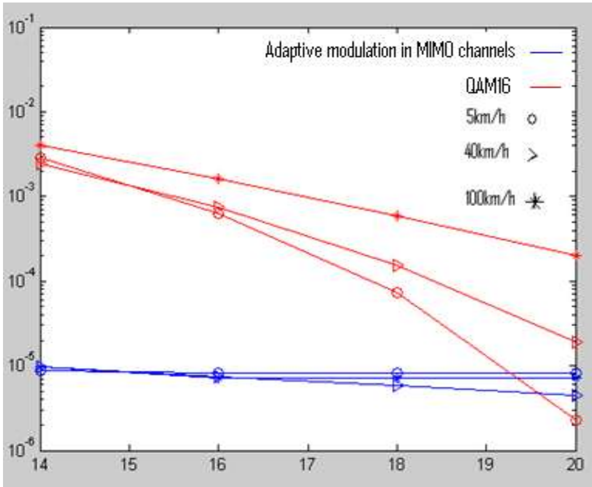

Fig. 11. Adaptive modulation in MIMO channels BER (results for QAM16)

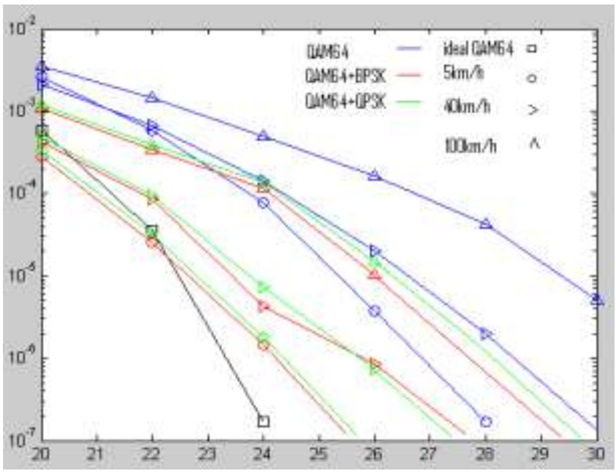

Fig. 12. Dual Modulation BER (results for QAM64)

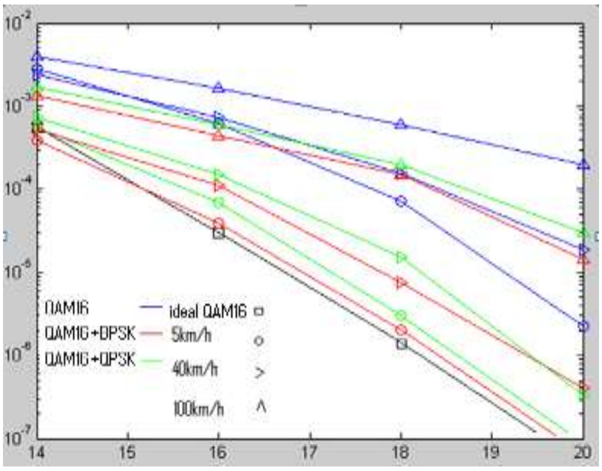

Fig. 13. Dual Modulation BER (results for QAM16)

Conclusions

The simulation results showed that the MIMO have a problem, because of the unequal received signal to noise ratio. The two solutions we used to solve this problem, the adaptive modulation in MIMO channels and the dual modulation showed effectiveness in enhancing the performance with high signal to noise ratio 20dB to 30dB for QAM64 and 14dB to 20dB for QAM16. The adaptive modulation in MIMO channels, showed very good effectiveness, but its use of a feedback from the receiver makes the system needs to adapt very fast to the change in the signal to noise ratio through each coherence time. Especially, with high velocity value the coherence time becomes very short, and the system adopting to the fast change in signal value with in short time becomes difficult. The dual modulation shoed good effectiveness with low velocities and doesn't need feedback from the receiver, but with high speeds it has less effect.

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